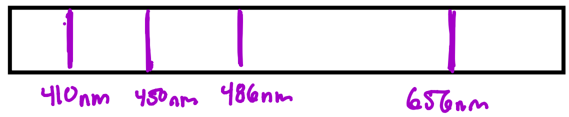
The Development of the Atomic Model (II)

Atomic Spectra

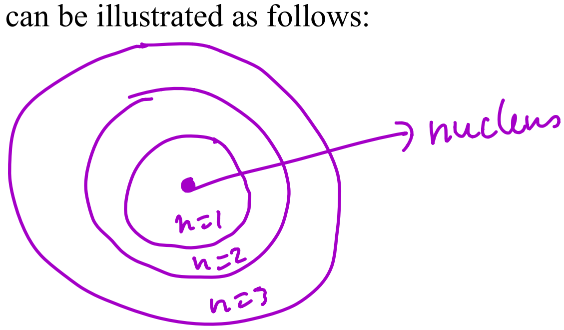
- When atoms are excited they emit specific wavelengths (photons) of light producing specific colours.
- The emitted light produces a series of different coloured lines separated from each other.
  - This pattern the lines is known a line spectrum or emission spectrum



- The line spectrum for each element is unique and thus can be used to identify the element.

Bohr (1913)

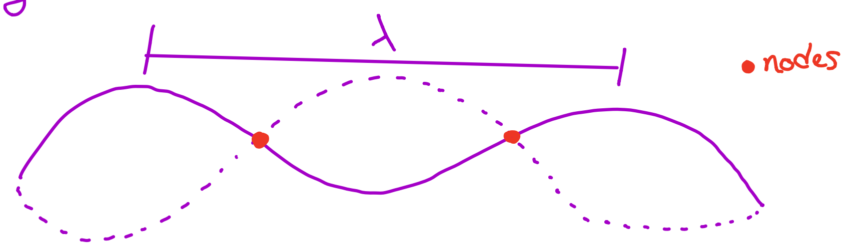
- Bohr developed a new model of the atom based on:
  - The work of Max Planck (1900) on the emission of electromagnetic energy from hot matter as quanta (or discrete packets) of energy.
  - The work of Einstein (1905) on the absorption and emission of photons in a "all or none" manner.
  - The emission of specific wavelengths (photons) of light by excited atoms.
  - The quantized energy of electrons in atoms (i.e., electrons can only absorb or release specific quantities of energy).
- Bohr proposed that:
  - Electrons exist in a series of "allowable" circular orbits around the nucleus, which are called energy levels (denoted by n).
  - Electrons in orbit do not radiate energy.
  - Electrons can move from one energy level to the other by absorbing or emitting energy.
  - Orbits closer to the nucleus are most stable (the lowest possible energy level in the atom is called the ground state)
- Bohr's model of the atom can be illustrated as follows:



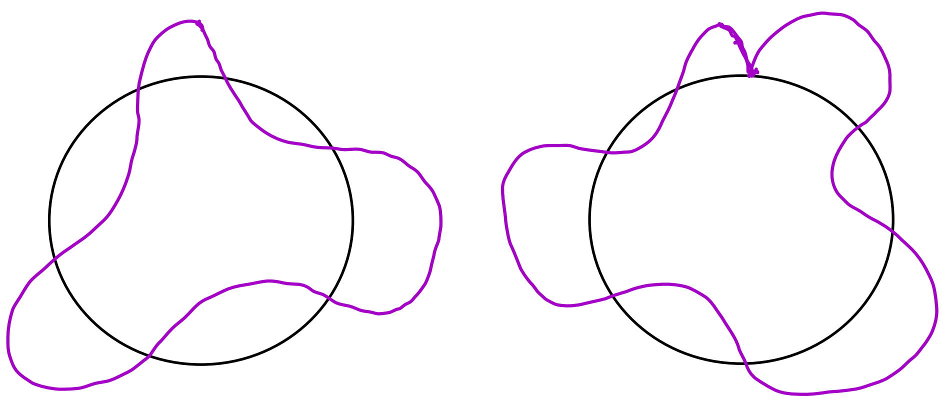
- Bohr's model explained the emission spectrum of hydrogen.
  - Hydrogen can only produce light corresponding to the energy differences between its allowable energy levels.
- Bohr's model failed to explain the line spectrum of atoms heavier than hydrogen.

Louis de Broglie (1924)

- Given that light has both wave and particle properties, de Broglie proposed that particles also have wave properties.
  - Developed an equation to determine the wavelength of any moving particle given its mass and speed. (implies that electrons also act as waves)
- Applying this idea to the atom, de Broglie proposed that an electron behaves like a standing wave.



  - If electrons are to behave like standing wave, de Broglie proposed that the wavelength must fit the circumference of its orbit exactly.



  - This means that there are only a defined number of energy levels, implying that energy is quantized.

Erwin Schrödinger (1926)

- Schrödinger used conventional wave equations to develop a quantum mechanical model of the atom (a model in which electrons are treated as waves).
  - The equation is known as the Schrödinger wave equation.
- The solutions to the wave equations (called wave functions):
  - Describe a region in the space around the nucleus of an atom called an atomic orbital where an electron spends 90% of its time.
  - An atomic orbital can be viewed as an electron cloud.
  - Contains three variables called quantum numbers that describe an electron's distribution in the atom.

Werner Heisenberg (1927)

- Proposed what is known as the *Heisenberg Uncertainty Principle*, which states that it is impossible to know simultaneously with exact precision, the position and momentum of a particle
- This showed that electrons did not move along an orbit.

Both speed and position can be found simultaneously in Bohr's model.

Max Born (1928)

- Showed that the square of wave functions can be used to determine the probability of finding an electron in an orbital.

A fourth quantum number

- In 1924, Otto Stern and Walter Gerlach discovered that electrons have their own individual spin, responsible for their magnetic field.
- This discovery also explained would explain some inconsistencies with hydrogen's emission spectrum when exposed to a magnetic field.
- A fourth quantum number was introduced to take into consideration the two possible values relating to the spin of an electron, which can be either "+1/2" or "-1/2".

Questions (Some based on questions found on p. 173 and 180 of the textbook)

1. What is the key difference between the models of the atom proposed by Rutherford and Bohr? What shortcoming of Rutherford's model does this key difference address?
2. Briefly describe how Bohr's model of the atom justifies the line spectrum of hydrogen.
3. How do electrons behaving as standing waves explain the quantized energy of the electron in a hydrogen atom?
4. Unfortunately, a classmate of yours had to miss today's class in which orbitals were discussed orbitals. How would you explain to your friend what an orbital is?
5. What is the Heisenberg Uncertainty Principle? How did it contradict Bohr's model of the atom?
6. What information do solutions to the Schrödinger equation provide?